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AUTHOR Gabel, Dorothy
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ABSTRACT

This information sheet examines three areas: (1) what research tells about problem-solving in chemistry; (2) why students have such difficulty in solving chemistry problems; and (3) if there are some ways of teaching students to solve problems that are more effective than others. From several research studies on problem-solving in chemistry, it is clear that the major reason students are unable to solve problems is that they do not understand the concepts on which the problems are based. Based on this finding (as well as others), it is recommended that teachers use various procedures to help their students become more successful in solving problems. They include using analogies and schematic diagrams, wait time, and concept maps. (JN)

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Research Matters... To the Science Teacher

PROBLEM SOLVING IN CHEMISTRY

By Dorothy Gabel

One of the major difficulties in teaching introductory chemistry courses is helping students become efficient problem solvers. Most beginning chemistry students find this one of the most difficult aspects of the introductory chemistry course. What does research tell us about problem solving in chemistry? Just why do students have such difficulty in solving chemistry problems? Are some ways of teaching students to solve problems more effective than others?

Problem solving in any area is a very complex process. It involves an understanding of the language in which the problem is stated, the interpretation of what is given in the problem and what is sought, an understanding of the science concepts involved in the solution, and the ability to perform mathematical operations if these are involved in the problem.

The first requirement for successful problem solving is that the problem solver understand the meaning of the problem. In order to do so there must be an understanding of the vocabulary and its usage in the problem. There are two types of words that occur in problems, ordinary words that science teachers generally assume that students know and more technical terms that require understanding of concepts specific to the discipline. Researchers have found that many students do not know the meaning of common words such as contrast, displace, diversity, factor, fundamental, incident, negligible, relevant, relative, spontaneous and valid.

Slight changes in the way a problem is worded may make a difference in whether a student is able to solve it correctly. For example, when "least" is changed to "most" in a problem, the percentage getting the question correct may increase by 25%. Similar improvements occur for changing from negative to positive forms, for rewording long and complex questions, and for changing from the passive to the active voice. Although teachers would like students to solve problems in whatever way they are framed they must be cognizant of the fact that these subtle changes will make a difference in students' success in solving problems.

From several research studies on problem solving in chemistry, it is clear that the major reason why students are unable to solve problems is that they do not understand the concepts on which the problems are based. Studies that compare the procedures used by students who are inexperienced in solving problems with experts show that experts were able to retrieve relevant concepts more readily from their long term memory. Studies have also shown that experts concepts are linked to one another in a network. Experts spend a considerable period of time planning the strategy that will be used to solve the problem whereas novices jump right in using a formula or trying to apply an algorithm.

In the past few years, science educators have been trying to determine which science concepts students understand and which they do not. Because chemistry is concerned with the nature of matter, and matter is defined as anything that has mass and volume, students must understand these concepts to be successful problem solvers in chemistry. Research studies have shown that a surprising number of high school students do not understand the meaning of mass, volume, heat, temperature and changes of state. One reason why students do not understand these concepts is because when they have been taught in the classroom, they have not been presented in a variety of contexts. Often the

instruction has been verbal and formal. This will be minimally effective if students have not had the concrete experiences. Hence, misconceptions arise.

Although the very word "misconception" has a negative connotation, this information is important for chemistry teachers. They are frameworks by which students view the world around them. If a teacher understands these frameworks, then instruction can be formulated that builds on student's existing knowledge. It appears that students build conceptual frameworks as they try to make sense out of their surroundings.

In addition to the fundamental properties of matter mentioned above, there are other concepts that are critical to chemical calculations. One of these is the mole concept and another is the particulate nature of matter. There is mounting evidence that many students do not understand either of these concepts sufficiently well to use them in problem solving. It appears that if chemistry problem solving skills of students are to improve, chemistry teachers will need to spend a much greater period of time on concept acquisition. One way to do this will be to present concepts in a variety of contexts, using hands-on activities.

What does this research imply about procedures that are useful for helping students become more successful at problem solving?

- Chemistry problems can be solved using a variety of techniques. Many chemistry teachers and most introductory chemistry texts illustrate problem solutions using the factor-label method. It has been shown that this is not the best technique for high school students of high mathematics anxiety and low proportional reasoning ability. **The use of analogies and schematic diagrams results in higher achievement** on problems involving moles, stoichiometry, and molarity.
- The use of analogs is not profitable for certain types of problems. When problems became complex (such as in dilution problems) students are unable to solve even the analog problems. For these types of problems, using analogs in instruction would be useless unless teachers are willing to **spend additional time teaching students how to solve problems using the analog**.
- Many students are unable to match analogs with the chemistry problems even after practice in using analogs. Students need considerable practice if analogs are used in instruction.
- When teaching chemistry by the lecture method, concept development needed for problem solving may be enhanced by **pausing** for a two minute interval at about 8 to 12 minute intervals during the lecture. This **provides students time to review what has been presented**, fill in the gaps, and interpret the information for others, and thus learn it themselves.
- The use of **concept maps** may also help students understand concepts and to relate them to one another.
- Requiring students to use a **worksheet** with each problem may help them solve them in a more effective way. The worksheet might include a place for them to plan the problem, that is list what is given and what is sought; to describe the problem situation by writing down other concepts they retrieve from memory (the use of a picture may integrate these); to find the mathematical solution; and to appraise their results.

Although the research findings are not definitive, the above approaches offer some promise that students' problem solving skills can be improved and that they can learn to solve problems in a meaningful way.

The National Association For Research in Science Teaching is an organization that seeks to improve science teaching through research. For further information, contact the NARST Executive Secretary:

Dr. Glenn Markle
401 Teacher College
University of Cincinnatti
Cincinnatti, Ohio 45221

For further information about this research area, please contact Dr. Dorothy Gabel at:

Education Building
3rd and Jordan
Bloomington, Indiana 47405